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LATE-FLOWERING PLANTS FROM NORTHERN NOVA SCOTIA, CANADA

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ABSTRACT. Over 90 species of herbaceous dicotyledonous plants, representing 62 genera and 19 families, were recorded in blossom from northern Nova Scotia, Canada, during November and December 2001. Most observations were made during 10–20 November, but 29 species were in flower after 10 December. The number of species flowering declined steadily with time, rather than declining precipitously after the first frost. Only 6 of these 92 species are specifically reported in the floras of Nova Scotia as flowering in November. Examination of plant collections in the primary Nova Scotia herbaria showed that our collections represent the latest flowering records for all but one of these species in Nova Scotia. Accordingly, our collection extends the known flowering times for these species by an average of 45 days. For most species the late flowering is interpreted as an extension of normal phenology in response to unusually warm autumn weather, but for some species (e.g., *Viola cucullata*, *Ranunculus acris*, *Fragaria virginiana*) it appears to represent a second flowering period. Our collections establish a base line of late flowering times that could be used as an indicator of regional climate change.

Key Words: climate change, flowering, global warming, Nova Scotia, phenology

The reproductive period of flowering plants is determined by external environmental constraints (both biotic and abiotic) and physiological adaptations to those constraints (Daubenmire 1974; Zeevaart 1962). In temperate zones, the growing and flowering season is abruptly terminated in autumn by waning sunlight intensity and falling temperatures, especially those that produce frost. Given that temperatures, and hence the length of the growing season, vary from year to year, it is natural to expect that the flowering periods of at least some plant species will be flexible enough to reflect those differences; many late-flowering species continue to grow until they are killed by frost. Hence, one effect of warmer temperatures or late frost in a given year would be an extension of the flowering season (Salisbury and Ross 1992).

Flexibility in plant flowering periods is pertinent to the question of global warming, which is anticipated to increase mean annual temperatures by 2–4°C in Atlantic Canada (Moore et al. 1999), with an attendant lengthening of the annual period of above-zero temperatures. Autumn of 2001 provided a glimpse of what the future might hold: the weather was exceptionally moderate from September through

December, with only a few (and mild) frosts late into the season, accompanied by warm temperatures and gentle rainfall. If plants can adapt to longer growing seasons associated with transient or directional changes in their environment, we predict that reproductive periods would be extended in concert with a lengthening frost-free period.

Here, we document the apparently extended periods of flowering in the flora of Antigonish County, on the northern mainland of Nova Scotia, Canada. To confirm that the season was unusually warm, we compared weather records for autumn 2001 against climate normals (long-term averages) for the area. Our data provide the latest records of flowering for most of these species in Nova Scotia, and thereby establish a base line against which extensions or contractions of the flowering season in future years can be compared.

Our observations began in October when casual observations of roadsides and meadows revealed that many late-summer and fall plants were unexpectedly still in flower. Synoptic observations of the day-to-day weather suggested that the autumn was unusually warm. We began keeping records of species in which flowering persisted as the autumn progressed. From early November onward we began a concerted effort to observe and collect any flowering plants still in blossom. These observations continued until flowering in all native and naturalized species in the local flora had ceased, in mid-December.

MATERIALS AND METHODS

Regional climate. Antigonish County occupies the northeast end of mainland Nova Scotia, on the eastern edge of Canada (Figure 1). As Nova Scotia is a peninsula protruding into the Atlantic Ocean, there is a strong maritime influence on the continental climate of the province. Annual mean temperature inland in Antigonish County is 5.6°C for 1916–1990; the mean is 18.1°C in July and −6.7°C in January, the greatest range for any part of the province. The growing season is about 200 days (Nova Scotia Museum 1996).

Because of the maritime influence there is a powerful moderation of temperatures along the coast compared with sites inland. In addition, seasonal changes are delayed and extended compared with regions at the same latitude in central Canada. A long warm autumn, interrupted by occasional storms moving up the Atlantic coast, is typical of northern Nova Scotia (Nova Scotia Museum 1996). Nighttime frosts begin inland in early October in most years but may be delayed by two to three weeks along the coast. Snow does not begin to accumulate until late December.

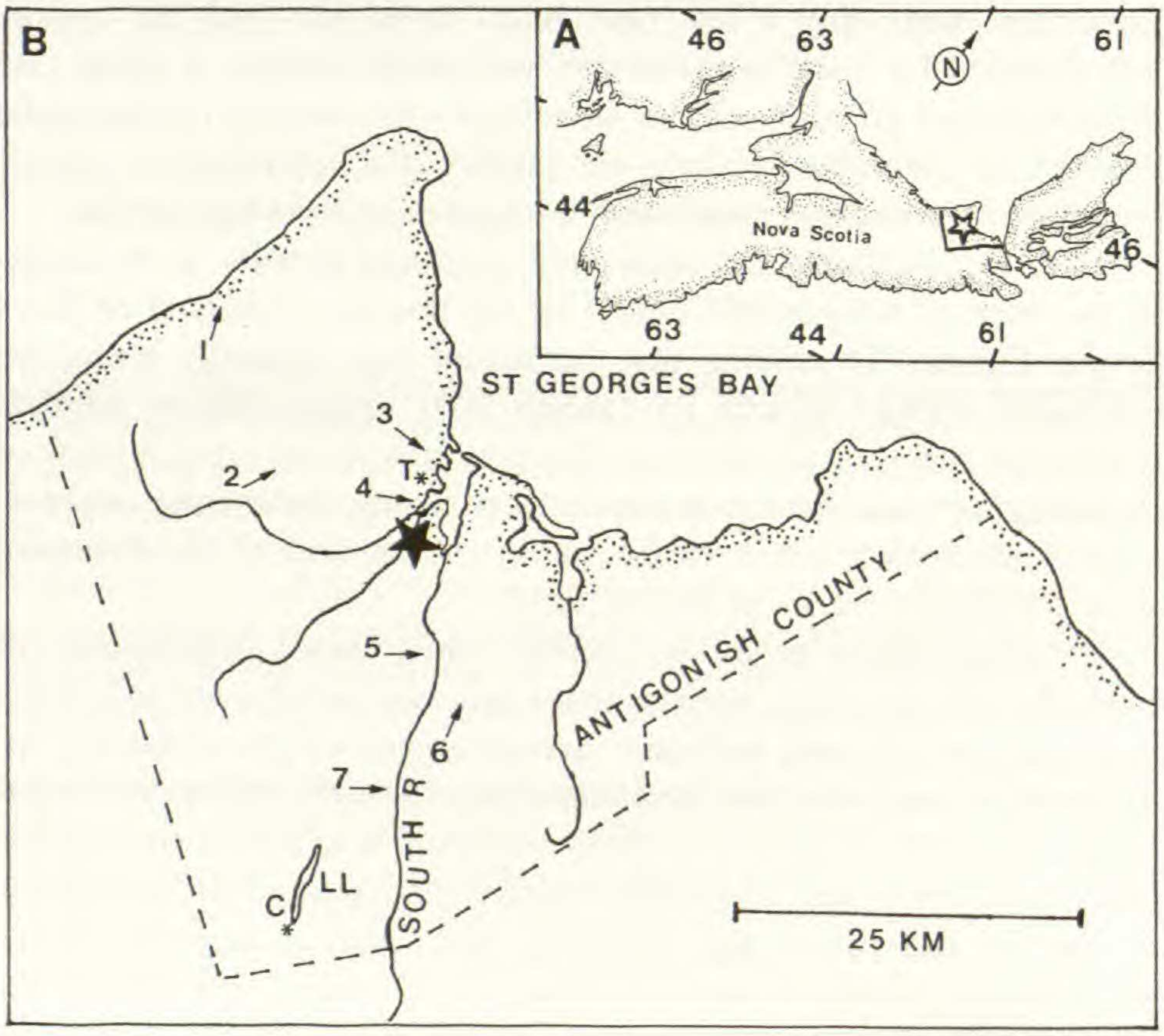

Figure 1. Map of Nova Scotia. A. Province, showing location of Antigonish County (star). B. Enlargement of Antigonish County showing sites of weather stations (*) at Collegeville (C) near Lochaber Lake (LL) and Town Point (T) and primary collecting sites: star = Antigonish Town; 1 = Malignant Cove; 2 = North Grant; 3 = roadside, Highway 337; 4 = Antigonish Landing; 5 = Dunmore Road; 6 = St. Andrews; 7 = Frasers Mills.

The Town of Antigonish lies on the coast adjacent to Northumberland Strait (Figure 1). The local climate of the town is therefore warmer in autumn and more moderate than sites even a few kilometres inland. The landscape of Antigonish County is composed of gently rolling hills defining shallow, wide river valleys. The varying elevations and aspects, coupled with a variety of land uses and vegetation types (chiefly residential, mixed forest, and farmland) creates many microclimates throughout the county. It is typical, for example, for river valleys to experience autumn frosts earlier than upland sites because of the accumulation of cooler air in depressions.

We obtained weather data from two standard Environment Canada weather stations at Antigonish and Collegeville. Daily records of minimum and maximum temperatures at the two sites for the months

Table 1. Summary of daily temperature data (°C) from a coastal station (Antigonish) and an inland station (Collegeville) in northern Nova Scotia, autumn 2001. Normals are 85-year averages (1916–1990) for Collegeville. [1]Daily temperature is average of maximum (Max.) and minimum (Min.) for each day. [2]Days with minimum temperature < 0°C. [3]Units are degree-days.

Month	Mean Temperature °C			Frost	Heat Units[3]	
Site	Max.	Min.	Daily[1]	no. of days[2]	> 5°C	< 0°C
September						
Antigonish	22.8	10.5	16.7	0	349.8	0
Collegeville	22.8	9.1	15.9	2	328.3	0
Normal	18.8	7.8	13.3	–	249.2	0
October						
Antigonish	17.2	5.0	11.1	4	192.1	0
Collegeville	16.1	3.9	10.0	5	163.8	0
Normal	13.0	3.3	8.2	–	111.9	0.3
November						
Antigonish	8.7	0.4	4.6	17	51.2	5.5
Collegeville	8.8	0.3	4.5	14	51.6	13.5
Normal	6.9	−0.9	3.0	–	30.8	19.8
December						
Antigonish	3.6	−2.6	0.5	25	12.5	31.7
Collegeville	2.6	−3.5	−0.5	27	8.5	58.5
Normal	1.0	−7.5	−3.2	–	5.1	130.5

of September through December 2001, along with precipitation and qualitative observations of sky conditions, were provided by the Atlantic Climate Centre of Environment Canada (Fredericton, New Brunswick). The Antigonish station is located in South Side Harbour, just outside the Town of Antigonish (45°37′N, 61°54′W; 30 m) and measures the coastal microclimate. The station at Collegeville (45°29′N, 62°01′W; 76 m) is located approximately 25 km inland (Figure 1).

We used climate normals from the Collegeville station, based on weather records from 1916–1990, as a base line against which to compare the weather in autumn 2001 (Table 1). Climate normals for Collegeville were downloaded from the webpage of the Meteorological Service of Canada, Environment Canada (www.msc-smc.ec.gc.ca/climate/index_e.cfm). The weather station at Antigonish is too recent (1990 onward) for climate normals to be established.

Plant collecting. We collected flowering plants in and about the Town of Antigonish. These collections were supplemented by additional collections in rural areas of Antigonish County, in particular along the valley of South River and along the roadside to Malignant Cove on the Northumberland Strait (Figure 1). Most species were found in waste ground in mixed herbaceous vegetation; however, collections were made from roadsides, agricultural land, regenerating woodlots, pasture land, and mixed forest. While we did not undertake a systematic survey of every habitat in the county we did make a concerted effort to seek out a variety of habitats and to thoroughly explore places where flowering plants were most persistent.

We collected only non-graminoid, herbaceous plants with conspicuous flowers. Grasses and some herbaceous species with cryptic flowers were excluded because it proved difficult to confirm whether they were fully in flower at the time of collection. No woody plants flower into fall in this region.

Collecting was initially terminated after 11 November because of a snowfall late in the day, followed by several days of heavy frost and subzero temperatures. Minimum temperatures for 12–15 November ranged from −2 to −6°C at Antigonish and from −3 to −6.5°C at Collegeville. Despite this apparently "killing" frost, many plants (17 species) were found in flower at a diversity of sites after 15 November, after the snow melted. Therefore we resumed collecting, and continued for as long as flowering plants could be found. The last collecting day was 15 December, when permanent snow cover began to accumulate.

All species in flower were noted during each sampling expedition, along with their habitat and general condition. At least one specimen of each species in flower was collected, pressed, and mounted. For some species, later or more conspicuously flowering specimens were also mounted. In the species list (Appendix), we have noted dates when plants were observed in flower after the date when a specimen was collected. Vouchers are deposited in the herbarium of St. Francis Xavier University, Antigonish, Nova Scotia (STFX). Phenology of species we collected was evaluated based on published accounts in Roland and Smith (1969) and Zinck (1998) and collections in the following herbaria: E. C. Smith Herbarium (ACAD), Nova Scotia Museum of Natural History (NSPM), and the A. E. Roland Herbarium (NSAC).

RESULTS

Weather. Temperature data from Environment Canada confirm that the autumn of 2001 was unusually warm in northern Nova Scotia (Table 1). Based on monthly averages for September through December, mean maximum, minimum, and daily temperatures at Collegeville for those months in 2001 were significantly warmer than the long-term average (t-tests, $P < 0.05$, $n = 4$), although the difference for daily minimum was barely significant. The daily maximum temperature averaged 4°C warmer in September, declining to 1.6°C warmer in December. Conversely, the difference in mean minimum temperature increased from 0.6°C to 4°C over the same period (October to December; Table 1). Mean daily temperature at Collegeville (the average of the daily maximum and minimum) was 1.5°C to 2.7°C warmer in 2001 than the long-term average. This is a substantial difference, equivalent in the short term to the degree of warming expected under projected increases in global CO_2 concentrations (Moore et al. 1999).

Calculation of heat units above 5°C, taken as the threshold temperature for plant growth, illustrates the extent of warmer weather in 2001. Heat units declined steeply from October to November as the days shortened; nevertheless, mean heat units in 2001 were 30–70% greater than the long-term average (Table 1). Similarly, negative heat units, calculated as the sum of degrees below zero for each daily minimum, summarize the frequency and severity of frost. Negative heat units were substantially less in November and December 2001 than the long-term average, indicating less severe frost (Table 1).

Average temperatures at the inland station, Collegeville, were about 1°C cooler than near the coast, except in November (Table 1). The first frosts occurred on 20 September (−2°C) and 30 September (−1°C) at Collegeville, but were delayed for a month at Antigonish (24 and 28 October). After September there was no marked difference in the frequency of frosts between the two sites, but because of the lower minima inland, frost there was generally more severe. There was a substantial difference in heat units between the two sites as well (Table 1).

Plant collections. A total of 92 species of herbaceous plants, representing 19 families, were found in flower in Antigonish County during November–December 2001 (Appendix; Table 2). All were dicots. One-third of the total (30 species) were native, with the remainder (62 species) being introduced from elsewhere, chiefly Europe (Zinck 1998). Although the greatest number of species was collected in early November, almost a third of the total (29 species) were still blooming after 10 December. All plants in our collection were terrestrial; despite regular inspections of aquatic habitats, we found no aquatic plants blooming in November. One specimen of *Polygonum*

Table 2. Distribution among families of late-flowering plants from Antigonish, Nova Scotia, in autumn 2001 in order of species richness. [1]Ratio of number of species collected to number of species listed in Zinck (1998).

Family	Number of Species Collected	Number of Species in Nova Scotia	Proportion of Known Species Collected[1]
Asteraceae	30	166	0.18
Brassicaceae	12	51	0.24
Fabaceae	7	41	0.17
Caryophyllaceae	7	35	0.20
Polygonaceae	7	41	0.17
Scrophulariaceae	5	38	0.13
Rosaceae	5	97	0.05
Lamiaceae	3	28	0.11
Apiaceae	3	30	0.10
Onagraceae	2	16	0.13
Malvaceae	2	7	0.29
Violaceae	2	15	0.13
Campanulaceae	1	8	0.13
Chenopodiaceae	1	23	0.04
Clusiaceae	1	9	0.11
Euphorbiaceae	1	9	0.11
Plantaginaceae	1	7	0.14
Ranunculaceae	1	24	0.04
Solanaceae	1	9	0.11
TOTAL	92	654	

sagittatum, a plant of damp ground, was collected from a sandbar bordering South River.

Several species were recorded based on single collections of one or very few individual plants. This group includes *Campanula rapunculoides*, *Hesperis matronalis*, *Viola cucullata*, *Polygonum persicaria*, and *P. sagittatum*. In several cases only a small population of individuals was present, growing in highly protected environments (e.g., *Cardamine pensylvanica*, *Centaurea nigra*, *Malva neglecta*, *Chaenorrhinum minus*, and *Dianthus armeria*). These species cannot confidently be said to be members of the late-flowering flora: the occurrence of a single plant blooming out of season could be a sport or a unique event caused by unusual habitat conditions, such as a heat-reflecting wall.

Our collections included members of 19 plant families of which 12 were represented by more than one species (Table 2). Greatest diversity occurred in Asteraceae (30 species) and Brassicaceae (12 species). These two families, along with the Caryophyllaceae, Fabaceae, and

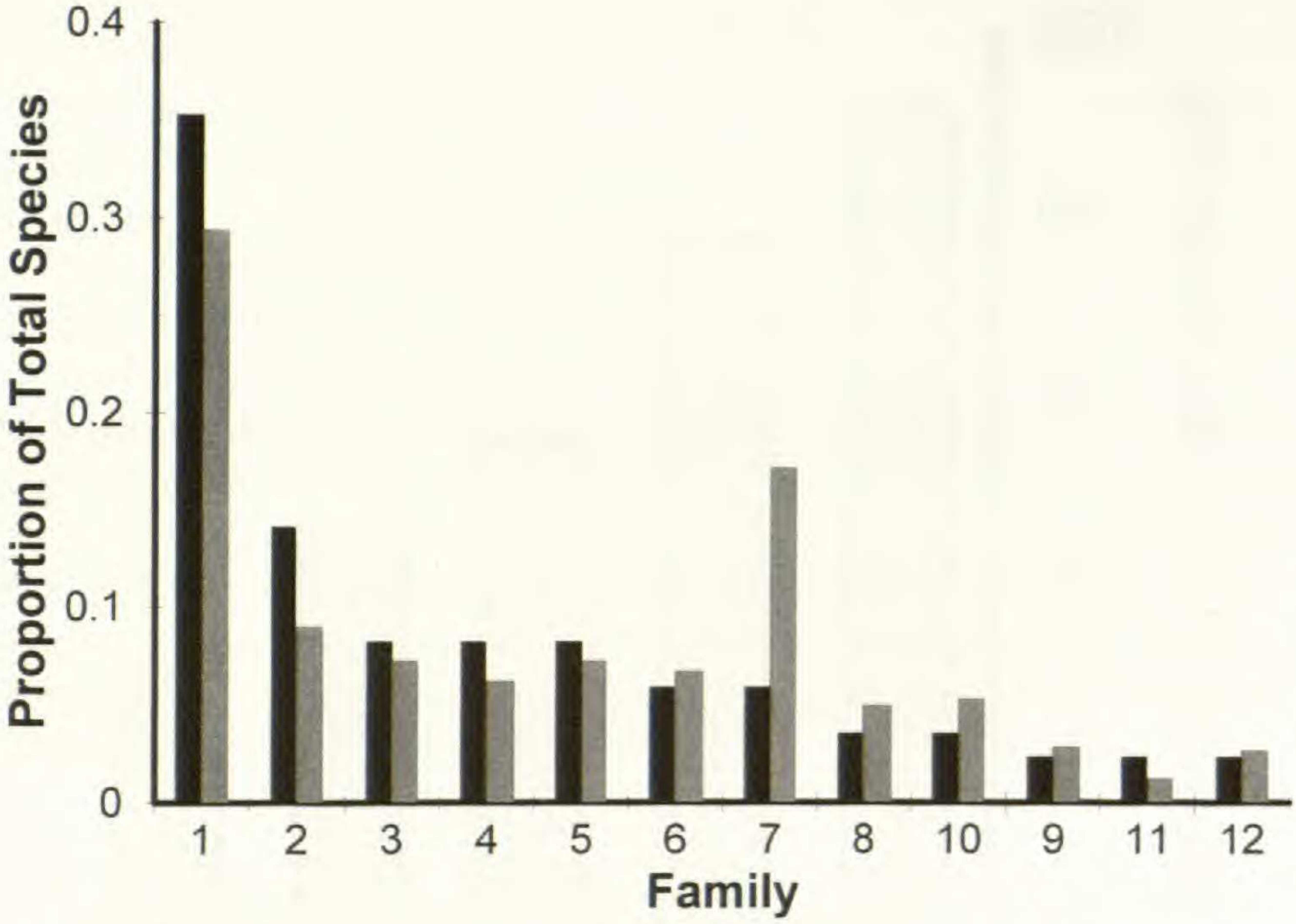

Figure 2. Proportions of species in the twelve families with more than one species in our collections. Dark bars indicate proportions in our collections; light bars indicate proportions in Zinck (1998). 1 = Asteraceae; 2 = Brassicaceae; 3 = Fabaceae; 4 = Caryophyllaceae; 5 = Polygonaceae; 6 = Scrophulariaceae; 7 = Rosaceae; 8 = Lamiaceae; 9 = Apiaceae; 10 = Onagraceae; 11 = Malvaceae; 12 = Violaceae.

Polygonaceae (7 species each) constituted almost 70% of all the late-flowering species. Asteraceae alone contributed almost a third of the total. The dominance of these families could be a consequence of a high proportion of late-flowering members, or merely the size of the family. In Figure 2, the number of species in each family is expressed as a proportion of the total number of species collected. Only the 12 most abundant families, those represented by more than one species in our collection, were included in the calculation. For comparison, the total number of species in each family as a proportion of the number of all species known from Nova Scotia (Zinck 1998) is also shown.

With the exception of the Rosaceae (7), the proportions of families in our collection are not very different from the proportions in the whole flora of Nova Scotia (Figure 2). There are proportionately more Asteraceae, Brassicaceae, Caryophyllaceae, and Polygonaceae among the late-flowering plants than in the whole flora, but the differences are not great. Hence, the dominance of Asteraceae among the late-flowering plants appears to be a result of the great number of species in this family, not a propensity toward extended flowering; the Asteraceae would be

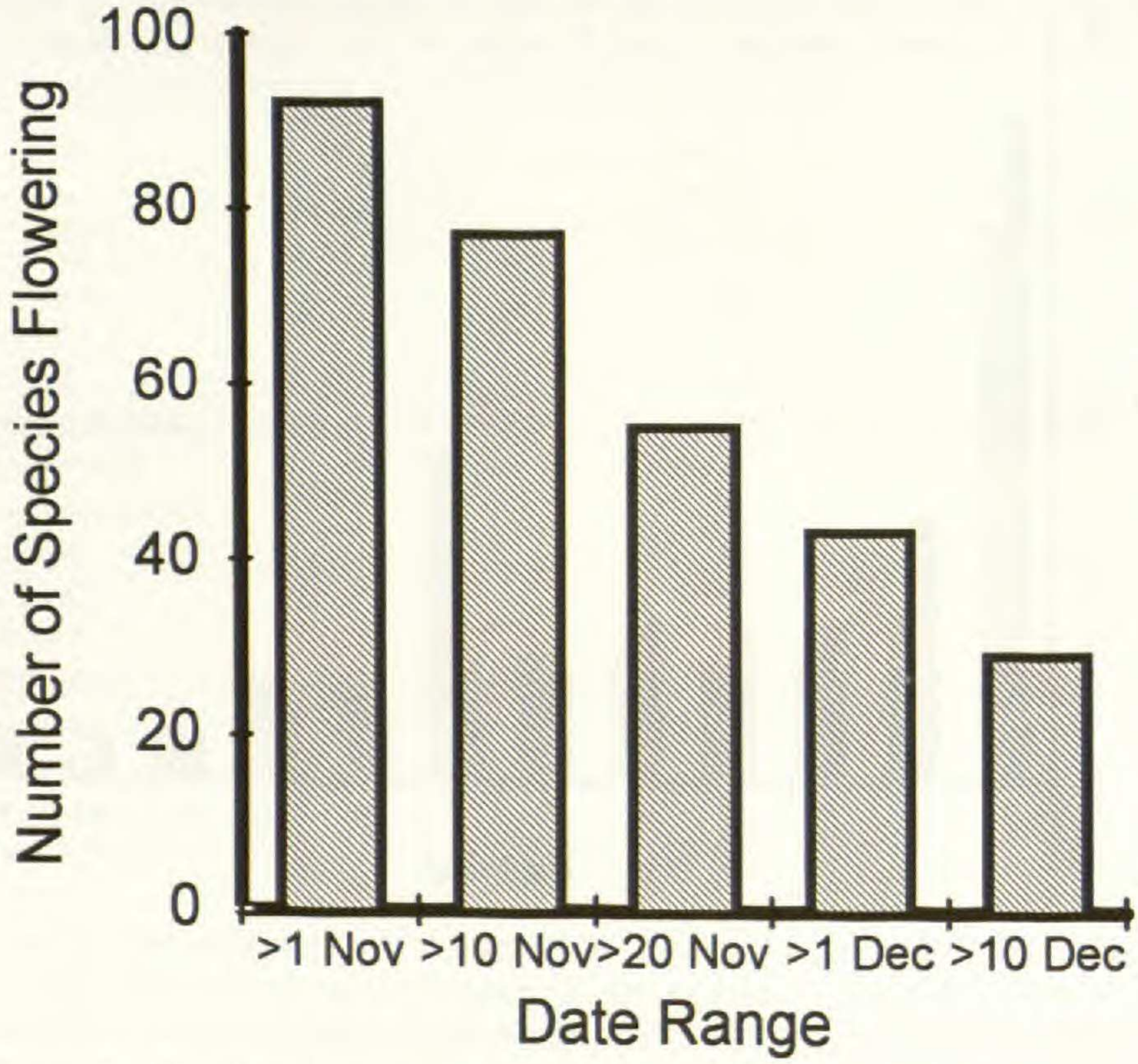

Figure 3. Number of species in flower in Antigonish County in 10-day intervals beginning 1 November 2001.

expected to dominate collections in any season. In fact, the only family that deviates conspicuously from the expected proportion is the Rosaceae, which is under-represented in the late-flowering plants. Most members of the Rosaceae in Nova Scotia bloom in spring (Zinck 1998).

To examine the temporal distribution of late-flowering plants, we divided the November–December season into five periods of 10 days each (Figure 3). Flowering ended in the middle of the fifth period, on 15 December. We assumed that each species was in bloom until the last day that flowers were observed, regardless of when the first flowering specimens were discovered. Hence, a species collected in flower for the first time on 18 November was assumed to have been blooming, undiscovered, before that date.

The growing season in 2001 did not end abruptly, as we had expected. Rather, the number of species in flower declined steadily from one period to the next (Figure 3), until the remaining plants died or were covered in snow on 15 December. The pattern in Figure 3 can be described with a simple linear function:

$$N = 107.2 - 16.0\ T$$

Where N = number of species in flower and T = sequential time period. The coefficient of determination (r^2) for this regression is 0.99 (n = 5).

Thus, it appears that, rather than truncating the growing season for all plants, bouts of cold weather during each period eliminated groups of species that had reached the limits of their cold tolerance. By the last period, after 10 December, only the hardiest species, or those populations growing in protected coastal sites, persisted. Nevertheless, these 29 species, nearly one-third of the total, were still blooming within the next five days. There was a major decline in flowering of native species relative to introduced species as the season proceeded. In early November 33% (30 of 92) of the species in flower were native; by mid-December only 15% (4 of 29) of the species were native (Figure 4).

DISCUSSION

Autumn of 2001 was remarkably mild throughout northern Nova Scotia. Comparison of Environment Canada weather records against long-term normals confirms that temperatures remained warm far longer in the fall than usual in 2001. While intermittent frosts began at about the same time in 2001 as in other years (usually the first week of October inland, unpub. data), below-zero temperatures were neither as frequent nor as severe (fewer negative heat units) as in a normal year. It is nevertheless surprising how many plant species continued to flower in the face of declining temperatures and intermittent freezing. Night temperatures regularly intercepted zero in late October, both at Antigonish and inland. After a brief warm spell in early November, night frosts became an irregular but frequent event for the rest of the month. Another brief warm spell began in December, before the final descent into winter temperatures. Despite the obvious cold, most of the plants we collected were robust and evidently healthy, and some had substantial local populations.

Our observations are consistent with long-standing conclusions of plant ecologists that sensitivity to frost, and hence the length of the growing season, varies widely among species (Daubenmire 1974). In Antigonish County, many species continued to grow and bloom despite being (apparently) repeatedly frozen several times each week, and sometimes covered with snow as well. Each period of cool weather, especially with nights of deep frost, led to the loss of progressively more

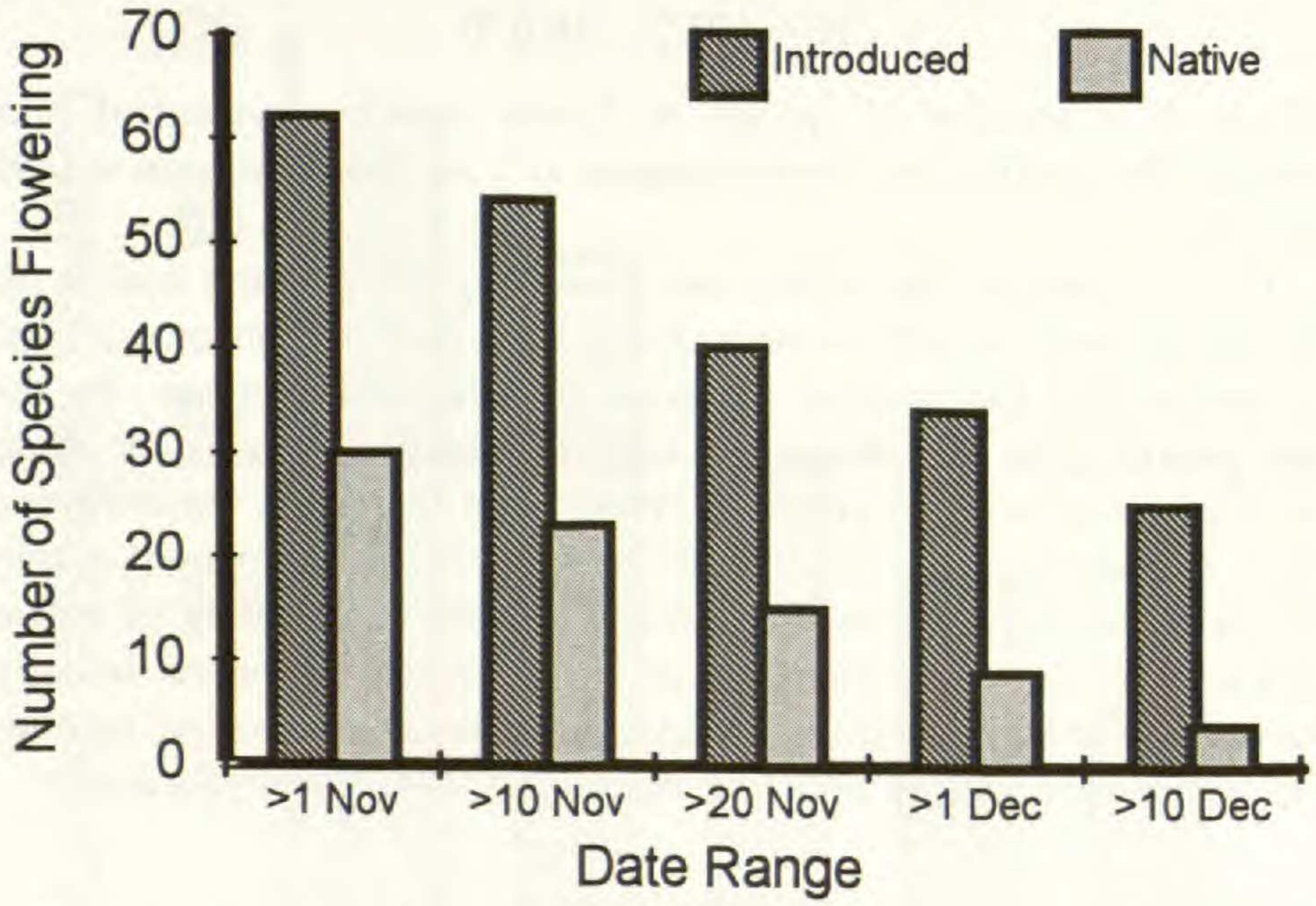

Figure 4. Numbers of introduced and native species flowering during successive 10-day intervals from early November 2001. Note the changing proportion of native species from 33% in early November to 14% in mid-December.

species from the flowering flora. Consequently, the number of species in bloom declined very steadily throughout the late autumn.

Accompanying the loss of flowering species was a steady shrinkage in the range of habitats in which flowering plants could be found. By mid-December, two groups included most surviving plants. The first group (e.g., *Cardamine pensylvanica*, *Leontodon autumnalis*, *Senecio vulgaris*) was found only in Antigonish, and many of the flowering individuals were in very protected habitats, sheltered from wind and perhaps receiving heat subsidies from nearby buildings. A second group (e.g., *Euphorbia helioscopia*, *Thlaspi arvensis*, *Trifolium pratense*) was found in agricultural fields or waste ground.

Most of the late-flowering plants we collected were growing in habitats that had been disturbed to some degree: roadsides, riverbanks, waste ground, gardens, and fields. We did not find any plants in bloom in November in forested land or in aquatic habitats. In fact, flowering in forest understoreys appeared to be over in October. Most of the plants in our collection are ruderals, growing as weeds and wildflowers in open ground where sunlight intensity is high and competition is low. It would be consistent with this *r*-selected life-cycle strategy that flowering time would be flexible, to take full advantage of extended growing seasons when they occur. In the more predictable, competitive environment of the forest, this kind of flexibility would confer less advantage. It is perhaps surprising though, that no emergent wetland plants were found blooming late.

The preponderance of weedy species in the late-flowering flora also accounts for the high proportion of introduced species. Roughly 25–30% of the flora of Nova Scotia is introduced (Nova Scotia Museum 1996), yet introduced species constitute fully two-thirds of our species list. The dominance of introduced species increased as autumn advanced. The majority of non-native species are weeds that were introduced with seeds and grain, and which have persisted in disturbed ground created by farming. These species typically have a very ruderal habit, growing quickly, seeding heavily, and showing great flexibility in phenology (Barbour et al. 1987). Native species dominate in more mature ecosystems such as forests, where we found no late-flowering plants.

We saw little evidence of selection in the taxonomic composition of the late-flowering flora. The species in our collection appear to be drawn from the flora of the region more or less in proportion with their species richness in each family. The conspicuous exception is the Rosaceae, whose members dominate the spring-blooming flora as the Asteraceae do the autumn. The only species in this family found flowering in late autumn were *Fragaria virginiana* and four species of *Potentilla*. The former species may be of special significance, however, because *F. virginiana*, along with a few other spring-flowering species (*Viola cucullata*, *Ranunculus repens*) was apparently entering a second round of flowering, as opposed to extending the flowering season. Futile autumn flowering in spring-flowering perennials has been known for a long time (Grainger 1939), and is prevalent whenever the onset of cold autumn weather is delayed (Daubenmire 1974).

We saw other evidence of "spring-like" behavior in fall 2001: flowers were expanding or breaking bud in *Sambucus* sp. and *Cornus stolonifera*, both of which normally bloom in spring or summer. Regardless of the mildness of the season, most flowering plants respond to day length as well as temperature in regulating their flowering periods (e.g., Fitter and Hay 1983; Zeevaart 1962). These observations therefore suggest metabolic confusion created by the combination of declining day length and mild temperatures.

The comparison of flowering times of the species in our collections with records in the three largest herbaria in Nova Scotia showed that for all but one species (*Centaurea nigra*), our collections represent the latest recorded flowering time for these plants in Nova Scotia. In fact, only six of the 92 species we collected are reported in Roland and Smith (1969) or Zinck (1998) as having flowering times that extend into November: *Capsella bursa-pastoris*, *Lamium amplexicaule*, *Matricaria matricarioides*, *Polygonum convovulus*, *Senecio vulgaris*, and *Stellaria media*. These authors have listed 106 species as flowering in October, 27 species as flowering in November, and 2 species as flowering in December. Of these 106 species, only 22 occurred in our collections. Thus an additional 84 species are potentially part of the November blossoming flora. These 106 species represent approximately 20% of the herbaceous dicot flora for the province. Hence, our list of 92 species is likely incomplete. Many new species were added to our collection in the final three weeks of the season. We attribute these late additions primarily to visiting new sites, as opposed to additional species coming into flower. Thus our list is probably highly constrained by collecting effort. Moreover, we cannot claim that our collections definitely establish the last date of flowering because we sampled destructively and non-systematically.

Compared with herbarium specimens and reported flowering seasons summarized in Roland and Smith (1969) or Zinck (1998), our collection extends the reported flowering season by an average of 45 days (range: 0 to 120 days; Figure 5). Notwithstanding the warm weather in 2001, a large part of this difference may be attributed to a lack of collection intensity during the late fall by previous workers in Nova Scotia. Herbarium records and phenological accounts in floras (e.g., Zinck 1998) generally reflect prime plants at the height of their development and not the extremes.

Based on a single year of collecting, it is not possible to attribute our records of late flowering in northern Nova Scotia to global warming. Nevertheless, our data suggest that the flowering phenology of many herbaceous species is very flexible. Therefore, if regional climate does change, it will be immediately reflected in the flowering periods of many herbaceous plants. In particular, we may expect more instances of autumn flowering among normally spring-blooming species if the regional climate grows warmer. It might prove advantageous to use species such as violets and wild strawberries as markers of climate change, because annual differences could be tracked by changes in the number of flowers produced by a small group of widespread species.

The bulk of the observations on flowering phenology that are associated with global warming refer to the earlier blooming of plants (e.g., Abu-Asab et al. 2001; Menzel et al. 2001; Post et al. 2001; Thorhallsdottir 1998). Phenological changes at the end of the growing

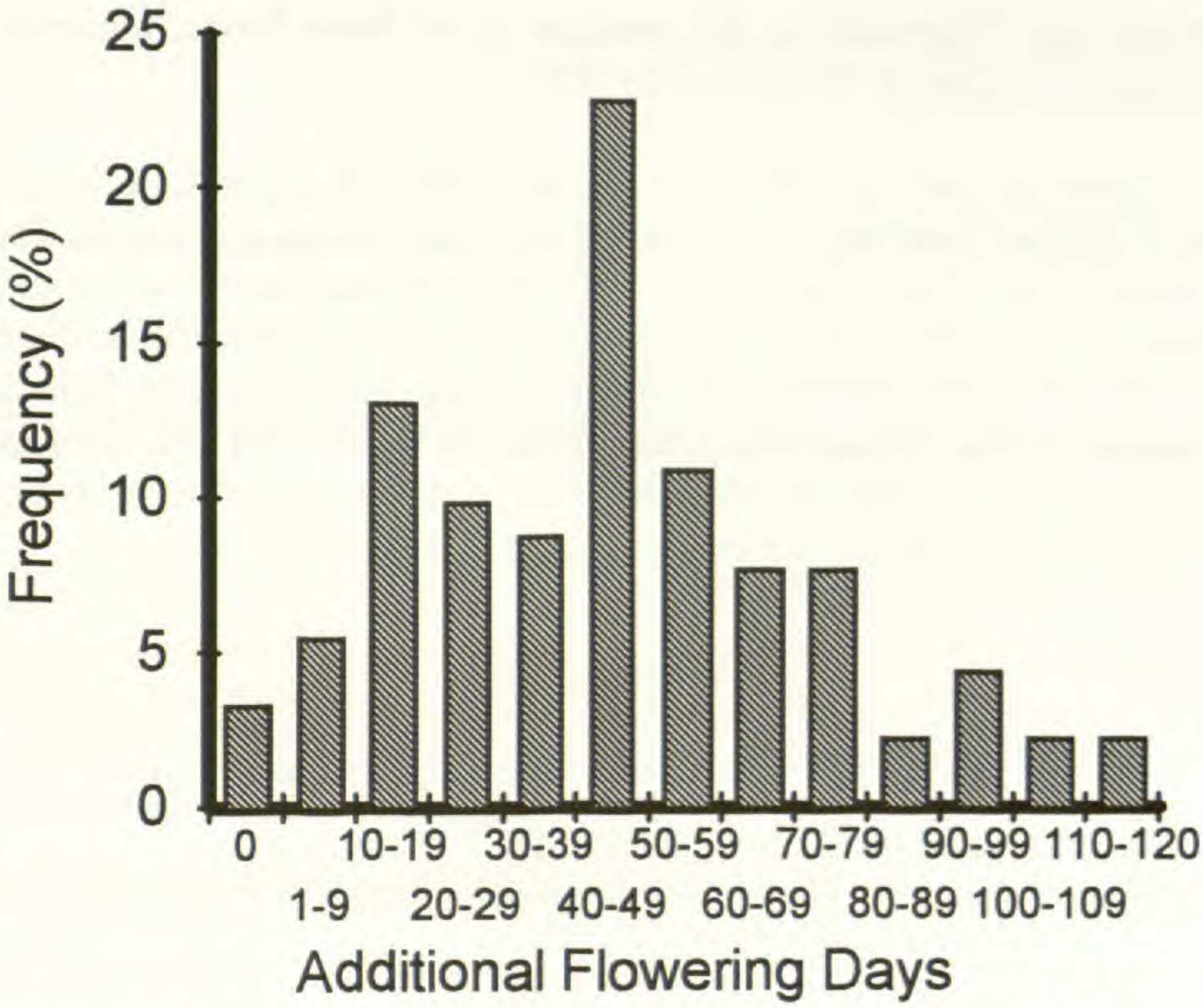

Figure 5. Extension of the flowering period in fall 2001, Antigonish County, Nova Scotia, relative to the latest herbarium specimens or flowering periods given in provincial flora. Data are frequencies among the 92 collected species falling into 10-day increments of additional flowering time.

season have been typically associated with lengthening of the period of vegetative growth rather than the period of reproduction (e.g., Menzel and Fabian 1999). Our observations suggest that flowering periods at the end of the growing season may show dramatic changes that reflect decreases in the frequency and intensity of frosts and slight increases in average daily temperature. Regardless of whether our flowering records reflect global warming, they do provide a base line against which future changes can be evaluated.

Although almost all of our collection or observation dates are the latest records of flowering for Nova Scotia, based on herbarium collections, our results cannot apply to the whole province. Antigonish County faces the Gulf of St. Lawrence in the northern mainland. Southern Nova Scotia, which has a decidedly milder climate and a longer growing season (Nova Scotia Museum 1996), may have many more late-flowering species than northern Nova Scotia. Indeed, we collected a specimen of *Raphanus raphanistrum* (wild radish) from disturbed ground near Yarmouth, at the southern tip of Nova Scotia, blooming through the snow on 25 December 2001.

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LITERATURE CITED

ABU-ASAB, M. S., P. M. PETERSON, S. G. SHETLER, AND S. S. ORLI. 2001. Earlier plant flowering in spring as a response to global warming in the Washington, DC, area. Biodivers. Conservation 10: 597–612.

BARBOUR, M. G., J. H. BURK, AND W. D. PITTS. 1987. Terrestrial Plant Ecology, 2nd ed. Benjamin/Cummins, Menlo Park, CA.

DAUBENMIRE, R. F. 1974. Plants and Environment: A Textbook of Autoecology, 3rd ed. John Wiley & Sons, New York.

FITTER, A. H. AND R. K. M. HAY. 1983. Environmental Physiology of Plants. Academic Press, London, U.K.

GRAINGER, J. 1939. Studies upon the time and flowering of plants. Anatomical, floristic and phenological aspects of the problem. Ann. Appl. Biol. 26: 684–704.

MENZEL, A., N. ESTRELLA, AND P. FABIAN. 2001. Spatial and temporal variability of the phenological seasons in Germany from 1951 to 1996. Global Change Biol. 7: 657–666.

——— AND P. FABIAN. 1999. Growing season extended in Europe. Nature 397: 659.

MOORE, T. R. et al. 1999. Litter decomposition rates in Canadian forests. Global Change Biol. 5: 75–82.

NOVA SCOTIA MUSEUM. 1996. The Natural History of Nova Scotia, Vol. 1: Topics and Habitats. Nimbus Publishing Ltd. and Nova Scotia Provincial Museum, Halifax, NS, Canada.

POST, E., M. C. FORCHHAMMER, N. C. STENSETH, AND T. V. CALLAGHAN. 2001. The timing of life-history events in a changing climate. Proc. Roy. Soc. London Ser. B, Biol. Sci. 268: 15–23.

ROLAND, A. E. AND E. C. SMITH. 1969. The Flora of Nova Scotia, 2nd ed. Nova Scotia Provincial Museum, Halifax, NS, Canada.

SALISBURY, F. B. AND C. W. ROSS. 1992. Plant Physiology, 4th ed. Wadsworth, Belmont, CA.

THORHALLSDOTTIR, T. E. 1998. Flowering phenology in the central highland of Iceland and implications for climatic warming in the Arctic. Oecologia 114: 43–49.

ZEEVAART, J. A. D. 1962. Physiology of flowering. Science 137: 723–731.

ZINCK, M., ed. 1998. Roland's Flora of Nova Scotia, 3rd ed. Nimbus Publishing Ltd. and Nova Scotia Provincial Museum, Halifax, NS, Canada.

APPENDIX

List of species observed flowering in Antigonish County after 1 November 2001. The month given for Flora indicates the latest flowering time listed for the species in Zinck (1998); it is assumed that this indicates the last day of the month. The date given under Herbaria indicates the latest flowering specimen found in any of the three major herbaria for mainland Nova Scotia (NSPM, ACAD, NSAC). Additional days indicates the number of additional flowering days in Antigonish County compared with the latest time given in Zinck (1998) or a herbarium collection. Question marks indicate missing data. Nomenclature follows Zinck (1998).

	Latest Flowering Time			
Species	Flora (Zinck 1998)	Herbaria (Nova Scotia)	Antigonish Collection	Additional Days
Achillea millefolium L.	Sep	1 Nov 1987	14 Dec	34
Anaphalis margaritacea (L.) Benth. & Hook.	Sep	18 Oct 1981	5 Dec	48
Aster ciliolatus Lindl.	Sep	?	12 Dec	73
A. cordifolius L.	Oct	18 Oct 1979	12 Dec	42
A. lateriflorus (L.) Britton	Sep	28 Oct 1987	10 Dec	43
A. novi-belgii L.	Sep	20 Oct 1973	10 Dec	51
A. puniceus L.	Sep	4 Oct 1930	11 Nov	37
Bellis perennis L.	Sep	6 Jul 1950	16 Nov	47
Bidens frondosa L.	Sep	29 Sep 1941	7 Nov	37
Brassica nigra (L.) W. J. D. Koch	Oct	8 Sep 1949	10 Nov	10
B. rapa L.	Oct	27 Sep 1991	12 Dec	43
Campanula rapunculoides L.	Aug	20 Sep ?	7 Nov	48
Capsella bursa-pastoris (L.) Medik.	Nov	2 Nov 1979	14 Dec	14
Cardamine pensylvanica Muhl. *ex* Willd.	Aug	11 Sep 1949	15 Dec	96
Centaurea nigra L.	Sep	20 Nov 1994	17 Nov	0
Cerastium vulgatum L.	?	27 Oct 1915	15 Dec	49
Chaenorrhinum minus (L.) Lange	Aug	4 Sep 1948	15 Nov	73
Chenopodium album L.	?	11 Oct 1930	17 Nov	36
Chrysanthemum leucanthemum L.	Jul	10 Oct 1996	26 Nov	46
Conioselinum chinense (L.) Britton, Sterns & Poggenb.	Sep	15 Sep 1955	11 Nov	41
Daucus carota L.	Sep	19 Nov 1994	20 Nov	1
Dianthus armeria L.	Jul	1 Oct 1967	19 Nov	48
Erigeron annuus (L.) Pers.	Sep	1 Oct 1945	16 Nov	45
E. strigosus Muhl. *ex* Willd.	Sep	12 Oct 1912	8 Dec	57

Appendix Continued.

Species	Latest Flowering Time: Flora (Zinck 1998)	Latest Flowering Time: Herbaria (Nova Scotia)	Antigonish Collection	Additional Days
Erucastrum gallicum (Willd.) O. E. Schulz	Oct	18 Sep 1954	12 Dec	43
Erysimum cheiranthoides L.	Sep	23 Oct 1978	15 Dec	53
Euphorbia helioscopia L.	Sep	21 Oct 1912	14 Dec	54
Euphrasia officinalis L.	Sep	10 Oct 1930	10 Nov	30
Euthamia graminifolia (L.) Nutt.	Sep	6 Nov 1994	10 Nov	4
Fragaria virginiana Duchesne	May	5 Sep 1986	27 Nov	83
Galeopsis tetrahit L.	Sep	10 Oct 1969	14 Dec	65
Hesperis matronalis L.	Jul	5 Sep 1994	17 Nov	73
Hieracium floribundum Wimm. & Grab.	Jul	16 Sep 1979	24 Nov	69
Hypericum perforatum L.	Aug	21 Sep 1979	5 Nov	45
Lamium amplexicaule L.	Nov	18 Sep 1979	8 Dec	8
Leontodon autumnalis L.	Oct	20 Nov 1994	16 Dec	27
Lepidium campestre (L.) R. Br.	Sep	3 Sep 1969	6 Dec	95
L. virginicum L.	Sep	17 Oct 1917	5 Dec	49
Linaria vulgaris Mill.	Aug	18 Nov 1869	5 Dec	18
Malva neglecta Wallr.	Oct	1 Nov 1912	14 Dec	44
M. rotundifolia L.	?	18 Oct 1992	10 Nov	22
Matricaria maritima L.	Aug	11 Oct 1981	15 Dec	65
M. matricarioides (Less.) Porter	Nov	13 Oct 1944	14 Dec	14
Medicago lupulina L.	Sep	7 Oct 1987	12 Dec	66
Melilotus alba Desr.	Aug	9 Nov 1979	20 Nov	11
M. officinalis (L.) Lam.	Aug	19 Sep 1971	11 Nov	53
Oenothera biennis L.	Oct	16 Oct 1915	24 Nov	24
O. perennis L.	Sep	6 Sep 1938	10 Nov	40
Pastinaca sativa L.	Jul	5 Sep 1962	5 Dec	92
Plantago lanceolata L.	Oct	11 Nov 1979	11 Nov	0
Polygonum arenastrum Jord. *ex* Boreau	?	24 Oct 1923	12 Dec	49
P. convolvulus L.	Nov	11 Oct 1972	24 Nov	0
P. pensylvanicum L.	?	18 Oct 1912	11 Nov	23
P. persicaria L.	Oct	19 Oct 1915	25 Nov	25
P. sagittatum L.	Oct	10 Oct 1917	10 Nov	10
Potentilla argentea L.	Aug	24 Sep 1917	5 Dec	73
P. canadensis L.	Jun	27 Jul 1955	24 Nov	120
P. intermedia L.	Jul	21 Jul 1962	18 Nov	110
P. recta L.	Jul	28 Oct 1951	16 Nov	18
Ranunculus repens L.	Sep	21 Aug 1996	25 Nov	55
Raphanus raphanistrum L.	Oct	2 Nov 1987	20 Nov	18

Appendix Continued.

Species	Latest Flowering Time: Flora (Zinck 1998)	Latest Flowering Time: Herbaria (Nova Scotia)	Latest Flowering Time: Antigonish Collection	Additional Days
Rumex longifolius Alph. de Candolle	Oct	20 Oct 1930	16 Nov	16
R. obtusifolius L.	Sep	20 Oct 1930	10 Nov	20
Senecio jacobaea L.	Sep	7 Oct 1973	9 Dec	63
S. vulgaris L.	Nov	24 Oct 1923	15 Dec	62
Silene latifolia Poir.	Sep	10 Oct 1919	7 Nov	27
S. vulgaris (Moench) Garcke	Aug	24 Aug 1967	8 Dec	100
Sinapis alba L.	Aug	30 Jul 1971	14 Dec	106
Solanum dulcamara L.	Sep	23 Sep 1990	17 Nov	47
Solidago canadensis L.	Aug	11 Oct 1930	5 Dec	55
S. puberula Nutt.	Sep	30 Oct 1991	10 Nov	10
S. rugosa P. Mill.	Sep	3 Oct 1995	29 Nov	56
S. sempervirens L.	Sep	18 Oct 1979	18 Nov	30
Sonchus arvensis L.	Sep	22 Oct 1970	22 Nov	30
S. asper (L.) Hill	Oct	18 Oct 1979	9 Nov	9
S. oleraceus L.	Oct	20 Sep 1992	15 Nov	15
Spergula arvensis L.	Oct	28 Oct 1987	12 Dec	43
Spergularia rubra (L.) J. & C. Presl.	Sep	5 Oct 1928	12 Dec	68
Stellaria media (L.) Cirillo	Nov	11 Sep 1952	12 Dec	12
Tanacetum vulgare L.	Aug	15 Oct 1969	12 Dec	58
Taraxacum officinale (L.) Weber	Jun	23 Sep 1995	15 Dec	84
Thlaspi arvense L.	Sep	?	12 Dec	73
Thymus serpyllum L.	Aug	4 Sep 1964	15 Nov	72
Tragopogon pratensis L.	Aug	24 Oct 1930	7 Dec	42
Trifolium hybridum L.	?	4 Aug 1953	5 Nov	93
T. pratense L.	Sep	2 Nov 1912	12 Dec	30
T. repens L.	?	20 Oct 1930	18 Nov	29
Veronica persica Poir.	Sep	7 Sep 1951	28 Nov	59
V. serpyllifolia L.	Oct	21 Sep 1987	27 Nov	27
Vicia cracca L.	Aug	16 Oct 1997	27 Nov	42
Viola cucullata Aiton	Jul	22 Aug 1975	10 Nov	73
V. tricolor L.	Nov	13 Oct 1944	5 Dec	5